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Mechanical Refrigeration of Cars for Freight Service

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# MECHANICAL REFRIGERATION OF CARS FOR FREIGHT SERVICE

BY

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# THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Leonard Woods Horr

ENTITLED Mechanical Refrigeration of Cars for Freight Service

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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Table of Contents.

# Mechanical Refrigeration of Cars for Freight Service.

## I. Introduction.

The problem of furnishing proper refrigeration for cars of perishable goods has interested refrigerating engineers for some time. This is particularly true in this country which has within its borders so many different climatic conditions. A large quantity of beef and mutton is exported every year. Butter, eggs and poultry must be brought from the localities where they are produced to the market in good condition and the high efficiency of the modern system is a testimonial to the ability of American railroad men. However, the increase in the consumption of perishable products and the difficulty of obtaining ice has led to numerous attempts to furnish mechanical refrigeration for freight cars. In foreign countries where the hauls are either very long or very short so that it is possible to run solid trains between points, mechanical refrigeration has been successful because one car containing the refrigerating apparatus can be attached to a train and run straight through to destination. But in this country the practice of running solid trains is not feasible since a train seldom reaches destination containing the same cars as when made up. Cars are switched on and off at various times and frequently a train will contain more cars of machinery, coal and other non-perishable freight than cars of refrigerated perishable products; hence the necessity of making each car a self contained unit.

## II. Construction of Refrigerator Cars.

Owing to the fact that this country leads all others in the quantity of refrigerated products transported within its borders, and due to the high efficiency of the service in this country, a refrigerator car of recent build by any of the large railroads may be taken as standard. Following are quoted some facts and figures presented to the American Association of Refrigerating Engineers in March 1910 by Mr. C. M. Secrist, General Manager of the Pacific Fruit Express Company. Referring to cars of recent build having an ice capacity of four thousand to eleven thousand pounds and showing the recent trend to larger ice tanks and increased insulation, he says;

"I quote below exact information as to inside and outside measurements of cars above referred to, also total cubic capacity as well as capacity between ice tanks:

Gauge.................................. 4'-8 1/2"

Length over sheathing...................40'-11 1/8"

Length inside of lining.................39'-10 3/4"

Length between ice tanks................33'-2 3/4"

Width inside of lining.................. 8'-2 3/4"

Height, top of floor to ceiling......... 7'-5 3/16"

Total cubic capacity....................2,444 cu.ft.

Available capacity between ice tanks.....2,032 cu.ft.

Capacity of both tanks..................11,000 lbs.

Length over end sills...................40'-9 5/8"

Length, inside to inside of coupler knuckles.43'-9 1/2"

Length over couplers....................44'-3 1/2"

Width over side sills.................. 9'-1 1/8"

Width over sub side sills............................9'-1 1/8"

Width over sheathing.................................9'-2 5/8"

Width over eaves.....................................9'-6"

Distance, center to center side sills...........30'-8"

Truck wheel base.....................................5'-6"

Total wheel base.....................................36'-2"

Height, top of rail to center of couplers...........34 1/2"

Height, top of sill to bottom of side plate.......7'-11 13/16"

Height of side door opening.........................5'-9 7/8"

Width of side door opening..........................4'-0"

Height, top of rails to eaves.......................12'-3 11/16"

Height, top of rails to top of brake shaft.......13'-5 13/16"

Height, top of rails to top of running board.....13'-0 1/2"

Light weight of each truck, about..............6,066 lbs.

General weight of car complete, about.........46,800 lbs.

These cars are equipped with Bettendorf under frame, which is of steel construction throughout. Linofelt insulation is used in the cars, being applied in three ply form, that is, three courses of insulation on top or ceiling, the same on sides, ends and floor of car. We find this to be ample protection from heat or cold.

We also find that the collapsible tank is giving entire satisfaction in every respect. The additional loading space obtained by raising bulk heads, figures about 15 percent. You will note from the general description that the total cubic capacity of the car is 2,444 cubic feet, while the available cubic capacity between ice tanks is 2,032 cubic feet, the difference between these figures being about 16.85 percent.

However, the bulk head when raised against ceiling, occupies some space, so we figure about 15 percent is a fair estimate.

We have received a great many favorable comments on our car and consider it as being the ideal refrigerator car."

## III. Present Icing Methods.

The present method of icing cars is partly governed by the Interstate Commerce Commission and partly by the railroads. Since the railroad is responsible for the condition in which the contents of the car arrives at destination provided that proper precautions are not taken, it is safe to assume that they will exercise due caution and that cars will not be sent through with insufficient icing merely for the sake of the saving on ice.

The Interstate Commerce Commission requires the railroads to furnish sufficient ice while in transit but does not specify as to who shall furnish the initial icing. There are several methods in use in this country. Sometimes the shipper supplies the initial ice and expects the car to go through without reicing; sometimes the railroad publishes a tariff naming refrigeration charges from loading station to destination, in this case the carrier would provide the initial icing. However in any case where the shipper provides the initial icing, he is at liberty to name the places at which the car is to be reiced and what quantity of ice is to be placed in the car each time.

The reicing stations on any through route are well planned to take care of the loss of ice which will take place between the reicing point and the preceeding one under average

weather conditions. For fruit coming from California to Chicago there are seven reicing stations about twenty-four to thirty hours run apart. For the run between Chicago and New York or Chicago and Boston on the New York Central Lines there are re-icing stations at Toledo, Cleveland, West Seneca and Albany, but the ordinary car of poultry, butter and eggs, destined New York, is only reiced at West Seneca, while cars destined for Boston are reiced at West Seneca and Albany. It is seen here that the reicing stations are about twenty-four hours run apart, as between Chicago and San Francisco.

## IV. Desirability of Mechanical Refrigeration.

Every refrigerating man will agree that mechanical refrigeration gives far better satisfaction than the use of ice. The reasons for this are principally two-fold:

First- A dryer refrigerator can be maintained, inasmuch as one does not have the moisture of the actual ice to contend with;

Second- The degree of refrigeration maintained by the mechanical apparatus is absolutely under control within the limits of the machine. For it is only necessary to regulate the expansion valve to control this.

In the refrigeration of freight cars for the transportation of perishable freight the two above-named advantages are particularly desirable. Some classes of perishable freight are peculiarly susceptible to moisture, notably eggs. Again perishable freight is divided into three great classes, Dressed Beef, Dairy Freight, and Fruit. Each class has its own special

kind of car adapted to meet the peculiar demands of its class. Also we find that various products require certain temperatures as; frozen products 28°, beef 32-34°, salt meats 36-38°, eggs 45-50°, dressed poultry 32-35°, and butter 45-50°. (These temperatures are all Fahrenheit.) Then there is another advantage in this process, namely, that the water resulting from the melted ice is not present, therefore the car is always ready for service and the railroad does not have to contend with wet floors, rotted sills etc. which, in the present car, must be constantly replaced.

The disadvantages of mechanical refrigeration for freight cars are principally as follows:

First.- The machinery is so complicated that the attendance of a competent mechanic is an absolute necessity. This adds an additional expense to the running expenses of the road.

Second.- The weight of the apparatus adds too much to the dead weight of the car.

Third.- Since each car would have to be a separate unit the initial expense is too large.

Fourth.- Up to the present time it has been impossible to devise a motive power for the apparatus which will answer for all the working conditions of the car.

## V. Attempted Systems of Mechanical Refrigeration.

At the present time there is no practical method of applying mechanical refrigeration to freight cars. Several attempts have been made, notably in this country and in Russia

on the Trans-Caucassian Railroad. Only one of these, however, the American system, is completely based on mechanical principles. The three systems which have been attempted are the Maksoutoff and Lire of Russia, and the Ethyl Chloride method of this country. Of these systems only one, the Lire, is actually in use; however a short review of the principles of each would be of interest.

### The Maksoutoff System.

Briefly, this system consists of forcing warm or cold air, according to whether the car is in use in winter or summer, through the compartment containing the freight. The car is a complete unit in itself for practical requirements have shown this to be absolutely necessary. Each car is divided into two parts, the storage room and the engine room, the partition separating the two parts being built of two walls about one foot apart, the engine side being well insulated. Between these two walls are placed galvanized iron trays which in the summer are filled with a cold brine solution at stations along the route. A fan driven by an electric motor sucks air in from the outside and forces it over the cold pans into the freight compartment. The electric current is furnished by a dynamo belted to the axle when the car is in motion and by an accumulator when the car is at rest. The pipes delivering the air are so fitted with valves and branches that the air may be forced through heated coils in the winter instead of over the brine pans. In the storage room, a thermostat, connected with electric bells, signals an attendant in the machine room when the temperature becomes either higher or lower than desired. The attendant, by

changing the speed of the fan, can so regulate the air supply as to give any desired temperature.

The objections to this system are:

First:- An attendant is required, thus creating extra expense.

Second:- Stations must be built along the route to supply fresh cold brine. This means a large expense of building and operation.

Again it does not seem that the cold brine solution with air blast has any advantage over the ice itself. Thus it is seen that there is little difference between this system and the American icing system, unless it be in the matter of expense, in which case the American system has a very decided advantage.

The Lire System.

This device, while not strictly an application of mechanical refrigeration, is worthy of note because it is the only system which is now in successful operation. The car has within its outside insulated wall and about six inches from it, an inner shell of galvanized iron. The space between is open to the outside air at the front and rear ends of the car. Inside this space and on the galvanized iron shell is a layer of jute or other absorbent material. Water, supplied from a tank on the roof of the car, is constantly sprinkled over this absorbent material and the air circulated in this space evaporates the water thus cooling the inside of the car.

This method, while working satisfactorily in Russia, would not be of use in this country because of different conditions of operation. In the United States a car frequently

must lay on a siding for a period of twenty-four hours or more, but in Russia solid trains are sent through from loading point to destination. In all other particulars this type of car would do the work of our refrigerator car with entire satisfaction.

The Ethyl Chloride Compression Machine.

This machine was invented by Mr. C. C. Palmer, of New York, and while found to produce satisfactory results in tests, it has not given satisfaction to the extent that it is used by any railroad.

Below are quoted some facts and figures from a paper by Mr. Palmer read at the First International Congress of Refrigerating Industries in Paris, France, during the year 1908.

"Ethyl Chloride is a monochloride of ethyl ($C_2H_5Cl$). Its specific gravity at 23°F. is 0.925. It boils at 54.5°F. The critical temperature is 365°F., and the latent heat at 23°F. is 174 B.t.u. It liquifies at 15 pounds pressure with condenser water at 65°F. It is a neutral chemical, consequently any metal can be used in constructing the machines."

"The process of manufacture is not complicated or difficult. It is manufactured in nearly all the European countries and there is no reason why it cannot be made in every country where refrigeration is required."

"It is evident that the boiling point of the chemical being 54.5°F. to produce the requisite degree of cold, the chemical must be operated under vacuum."

Mr. Palmer finds that the ordinary reciprocating compressor is hard to seal for vacuum without a careful attendant, therefore he uses a rotary compressor with sliding blades set

eccentrically on the cylinder and the axis of rotation almost in the neutral point. But the strong point in his machine is that there is a sufficient excess of pressure over vacuum to force the lubricant (glycerine) outward, thus increasing lubrication for the bearings and journals and removing all liability of leakage of air from this source. For power to drive the compressor he uses a belt connected to a pulley on the axle. In connection with this he uses a set of gears which provide for reversals in direction of motion and which can be changed for the speed at which they are to run. He plans to ascertain the probable speed over a certain division before leaving the division point and set the gears accordingly.

The chief objections to Mr. Palmer's plan are:

First:- An attendant is an absolute necessity, thus creating an extra expense to the railroad.

Second:- The device is costly to install.

Third:- The plan of taking motive power from the axle is an absolute failure owing to the fact that the car is not always in motion. For instance take a car from one of the western shipping points loaded with perishable freight for export from New York. It might arrive in Chicago just too late to be put on the through New York train and have to stand in Chicago yards for twenty-four hours. During this time there would be no means of refrigerating the car and the result would be a carload of damaged freight for which the road would have to pay, owing to the fact that they had contracted to supply all necessary refrigeration.

These are the principal facts to which the failure of the Ethyl Chloride process may be attributed.

## VI. Outline of System proposed by this Thesis.

In this thesis it is proposed to investigate the possibilities of an ammonia absorption system established as a complete unit in each car. The heat required to generate the ammonia gas in the still will be taken direct from the engine in the same manner as steam is used to heat Pullman cars and day coaches. The cooling water for the absorber and condenser will be taken from a small tank located at one end of the car. The water will be circulated by means of a steam pump and cooled by exposure to the air through a radiator on the roof of the car, thus circulating the water and using it over again as is done in water cooled automobile engines. It will be necessary to use a brine system instead of the simpler expansion system owing to the injurious action of ammonia vapor on some classes of perishable freight should any leaks occur in the pipes due to switching and bumping of the cars in the yards.

Owing to the high temperature of the outside air during July and August when refrigeration is most required, the initial temperature of the cooling water was taken as 90°F. it being judged that this would be a fair figure. To eliminate any possible error from this source a very large factor of safety has been used throughout.

## VII. Data.

In securing data on which to base the calculations for this design, access was secured to the records of one of the dairy

lines of the New York Central road, and from the following table, showing the number of the car, date of shipment from Chicago, initial icing, ice remaining and additional added at Albany and ice remaining on arrival in New York City, the total ice consumed during the trip was computed and an average taken for nineteen cars as shown below:

| Date | No. | Initial ice | West Seneca left | West Seneca add | New York left | Total |
|---|---|---|---|---|---|---|
| 7/6 | 12986 | 6000 | 1500 | 2500 | 500 | 8000 |
| 7/1 | 12502 | 7800 | 1500 | 2500 | 500 | 9800 |
| 7/10 | 15283 | 4800 | 2000 | 2000 | 2500 | 4300 |
| 7/17 | 15064 | 4800 | 3000 | 1000 | 2500 | 3300 |
| 7/18 | 18269 | 4000 | 2000 | 2000 | 1500 | 4500 |
| 7/21 | 9771 | 4000 | 2000 | 2000 | 500 | 5500 |
| 7/19 | 12177 | 7500 | 5500 | none | 3000 | 4500 |
| 7/23 | 18223 | 4000 | 1000 | 3000 | 1500 | 5500 |
| 7/23 | 14233 | 4000 | 1000 | 3000 | 2000 | 5000 |
| 7/24 | 13381 | 4000 | 2500 | 1500 | 700 | 4800 |
| 7/24 | 12067 | 4000 | 1000 | 3000 | 1000 | 6000 |
| 7/25 | 12662 | 4000 | 1000 | 3000 | 1500 | 5500 |
| 7/28 | 13843 | 7800 | 2000 | 2000 | 800 | 9000 |
| 7/29 | 12465 | 4800 | 2000 | 2000 | 2500 | 4300 |
| 8/11 | 14478 | 4000 | 2000 | 2000 | 2000 | 4000 |
| 8/11 | 15370 | 4000 | 2000 | 2000 | 2000 | 4000 |
| 8/13 | 9095 | 4000 | 2000 | 2000 | 2500 | 3500 |
| 8/15 | 37335 | 4000 | 3000 | 1000 | 1000 | 4000 |
| 8/16 | 12790 | 4800 | 2000 | 2000 | 3000 | 3800 |
| | | | | | | 99300 |

Average $\frac{99300}{19}$ = 5226 pounds

From this table it is seen that the average ice consumption was 5226 pounds or roughly 5000 pounds. Figuring on an average time of 72 hours for the run, which was found to be the case for these particular cars, and allowing 144 B.t.u. per pound of ice it is readily calculated that the average refrigerating effect was 15000 B.t.u. per hour.

From a paper on "Transportation of Perishable Products" by Mr. J. M. Culp, Vice President of the Southern Railway, read at the International Congress of Refrigerating Engineers at Berne, Switzerland, in 1910, the following temperatures for the safe transportation of various dairy products were taken:-

Eggs 45-50° F.

Dressed Poultry 32-35° F.

Butter 45-50° F.

The lowest of these is seen to be 32° for dressed poultry, hence this was assumed as a temperature for the cooler under maximum conditions.

All formulae were taken from Siebel's Compend of Mechanical Refrigeration as this is considered a standard work. It contains tables showing properties of ammonia, percentages of weak and strong liquor, sizes of standard generators etc.

The following assumptions were made as to the working conditions of the apparatus:-

First:- The refrigerating effect is to be 15000 B.t.u. per hour per car.

Second:- The outside temperature is 90° F.

Third:- The ammonia leaves the generator at 95° F. or 185 lbs. per sq. in. gage pressure.

Fourth:- The strong liquor is 40 percent anhydrous ammonia, and the weak liquor 20 percent.

Fifth:- The temperature of the cold room is 32° F.

Sixth:- Four pounds of strong liquor are circulated for every pound of ammonia gas required.

Seventh:- The strong liquor leaves the absorber at 110°F.

## VIII. Calculations.

The heat removed per pound of anhydrous ammonia is expressed by the following formula:

$$r = h_1 - ( t - t_1 ) s$$

where $h_1$ = heat of volatilization of one pound of ammonia at the temperature $t_1$ of the refrigerator.

$t$ = temperature of liquid anhydrous ammonia.

$s$ = specific heat of ammonia = 1.

substituting in this formula

$$r = 535.6 - ( 90 - 32 ) \times 1 = 477.6 \text{ B.t.u.}$$

The weight of anhydrous ammonia to be circulated is then

$$w = \frac{15000}{477.6} = 31.5 \text{ lbs. per hour.}$$

The heat $H_1$ to be removed in the condenser is evidently the latent heat of volatilization of ammonia at the temperature of the outgoing circulating water multiplied by the weight of anhydrous ammonia or

$$H_1 = 31.5 \times 495.3 = 15600 \text{ B.t.u. per hour.}$$

The heat $H_2$ removed in the absorber is composed of three parts:

(1) The heat developed by the absorption of one pound of

ammonia in the poor liquor, $H_n$.

(2) The heat brought into the absorber by a corresponding quantity of poor liquor, $H_g$.

(3) The negative heat brought into the absorber by one pound of the refrigerated ammonia vapor, $H_v$.

Hence

$$H_2 = H_n + H_g - H_v$$

The heat of absorption per pound of ammonia circulated may be found in a table page 164 of Siebel's Compend. For ammonia working between 20 and 40 as the percents of anhydrous ammonia in the weak and strong liquor, this is found to be 795 B.t.u. Multiplying this by the weight of anhydrous ammonia circulated per hour

$$H_n = 31.5 \times 795 = 25000 \text{ B.t.u. per hour.}$$

The heat brought into the absorber by the poor liquor is calculated by the following formula:

$$H_g = (P_2 - 1) \times 5 \times S \times w$$

where $P_2$ = pounds of rich liquor circulated per hour.

$S$ = specific heat of poor liquor = 1.

Substituting in this formula

$$H_g = (4 - 1) \times 5 \times 1 \times 31.5 = 471 \text{ B.t.u. per hour.}$$

The negative heat brought into the absorber by the refrigerated ammonia vapor is

$$H_v = (t - t_1) \times .5 \times w$$

where

$t$ = temperature of the strong liquor leaving the absorber.

$t_1$ = temperature in the refrigerator.

Hence

$$H_v = (110 - 32) \times .5 \times 31.5 = 1235 \text{ B.t.u. per hour.}$$

Combining $H_n$, $H_g$ and $H_v$, $H_2$ the heat removed in the absorber is

$$H_2 = 25000 + 471 - 1235 = 24236 \text{ B.t.u. per hour}$$

The heat, $W_1$, brought into the system by the steam is found by adding the heat, $H_1$, removed in the condenser to the heat, $H_2$, removed in the absorber and subtracting the heat of the required cooling effect or

$$W_1 = 15600 + 24236 - 15000 = 24836 \text{ B.t.u. per hour.}$$

Assuming the steam to enter the generator at a pressure of 20 pounds per sq. in. gage and that the generator has an efficiency of 50 percent, the weight of steam required per hour is

$$W = \frac{24836}{1166 \times .5} = 42.5 \text{ lb. per hour.}$$

To this must be added the steam consumption of the pumps in order to obtain the total steam consumption.

The condenser water will be stored in a small tank and circulated through the system by a small circulating pump. In order to economize on cooling water the machine has been designed so that the water enters the condenser at 90° and leaves at 95°, from there it passes to the absorber where its temperature is raised to 110° and it is then cooled by exposure to the air to 90° from which it repeats the cycle.

The heat to be removed in the condenser is 15600 B.t.u. per hour. Allowing a 5° rise in temperature of the cooling water this would require

$$\frac{15600}{60 \times 5} = 52 \text{ lb. of water per minute.}$$

The heat to be removed in the absorber is 24236 B.t.u. Allowing a rise in temperature of 15° this would require

$$\frac{24236}{15 \times 60} = 26.93 \text{ lb. of water per minute.}$$

Since the same cooling water is to be used for both condenser and absorber it will be necessary to use the larger quantity, 52 pounds per minute.

This water after leaving the absorber is to be cooled to 90° by contact with the air through coils on the roof of the car. This will require the removal of

$$52 \times (110 - 90) = 1040 \text{ B.t.u. per minute.}$$

The surface of exposed pipe necessary to accomplish this is given by Professor Hoffman in his book on Heating and Ventilating as

$$R = \frac{H}{k\left(t_w - \frac{t_1 + t_o}{2}\right)}$$

where

$R$ = square feet of exposed pipe surface.

$H$ = B.t.u. to be removed.

$t_w$ = temperature of entering water

$t_1$ = temperature of leaving water.

$t_o$ = temperature of the air

$k$ is a constant depending on the velocity of the air and is determined by the expression

$$k = 2 + 1.3\sqrt{v}$$

where $v$ is the velocity of the air in feet per second.

Assuming that the train runs at an average speed of thirty miles an hour

$$k = 2 + 1.3\sqrt{29.3} = 9$$

and

$$R = \frac{1040}{9(110 - 90)} = 5.78 \text{ sq. ft.}$$

## IX. Design of the Apparatus.

Since the amount of room available in the car for the apparatus is small, it will be necessary to use every possible economy of space in installing it. The engine room, in order to have the loading capacity the same as in the present car, can only be as large as are the combined ice tanks at present. Accordingly the machine room will be roughly 6 1/2 feet long, 8 feet 3 inches wide and 8 feet 4 inches high. The vertical type of generator, absorber, condenser and brine cooler will be used since they take less floor space and have the advantage that all pipes may be either above the head or beneath a false floor, thus allowing a man to get into the room should occasion require. The size of the various shells are given in Siebel as approximately 20 x 60 inches, however, a space 24 x 72 has been allowed for each.

The tank for cooling water will contain considerable water in excess of what is required. As calculated 52 pounds of water are required per minute. Water weighs 62 1/2 pounds per cubic foot, so, by making the tank cover the roof of the machine room and 1 1/2 feet in depth, there are roughly 96 changes provided for, giving the water approximately 1 1/2 hours to cool in the radiator after leaving the absorber until it reenters the condenser.

In order to cut down the weight of the apparatus as much as possible the generator has been designed to use steam at 20 pounds pressure. If the pumps use steam at this same pressure they will necessarily be large and cumbersome in order to develop the required power. Accordingly steam will be sent

back from the engine at 50 pounds pressure and run through a reducing valve before entering the generator.

The pipe in the store room will be designed for one square foot of pipe surface to 12 1/2 cubic feet of space. This differs somewhat from the rule used by large cold storage houses, but the difference is on the safe side, consequently there will be a certain amount of reserve refrigerating power in case anything happens to the machine. Pipe two inches in diameter has a surface of 1/2 square foot to one linear foot. Since the car has a capacity of 2,032 cubic feet there will be 164 square feet of pipe surface or 328 linear feet of pipe required. This will mean a coil of 2 inch pipes, 4 pipes deep, extending around the car.

For the cooling water coils on the roof only 6 square feet of surface is required theoretically, therefore if one inch pipe is run several times the length of the car and back there will be ample surface with a liberal factor of safety. It might be advisable to place the cooling coil in the form of a small vertical radiator, no higher than the brake shaft, in order to insure better air circulation, but this is a matter which would have to be determined by experiment.

All pipes connecting the various pieces of apparatus will either be at least 6 feet above the floor or under a false floor, thus permitting space for a mechanic to enter for the purpose of repairs and overhauling. A small door on the end gives access to the engine room for this purpose. Figure I shows the general arrangement of the car complete.

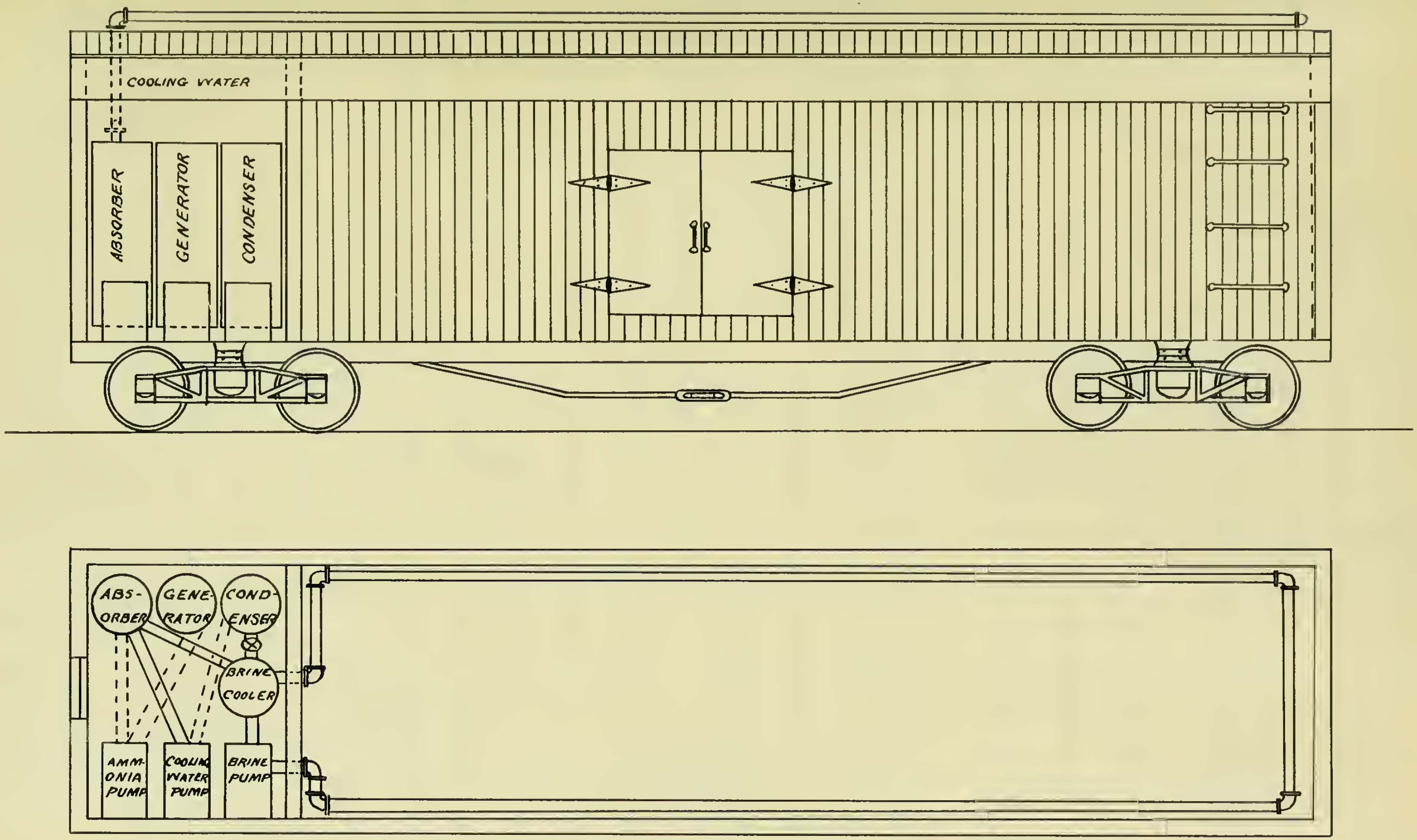


FIGURE I.

SKETCH OF CAR SHOWING INSTALLATION OF ABSORPTION APPARATUS.

SCALE $\frac{3}{16}$ IN. = 1 FT.

X. Discussion of Proposed Plan.

In discussing the advantages and disadvantages of the proposed system, it is necessary to consider the following points:-

(1) Will the apparatus operate at all times whether the car is standing or in motion?

(2) Will it require an attendant to operate it?

(3) Will it take up more room in the car than the present ice boxes and will its weight be enough more to noticeably increase the dead weight of the car?

(4) Will it take so large a quantity of steam from the locomotive as to materially affect the tractive power of the engine?

(5) Will it require a different construction of car so that it will be impossible to install this system in the present cars?

(6) Will its cost be prohibitive?

The various points will now be taken up in order.

(1) As designed at present the machine will not operate while the car is standing on a siding unless the engine is connected to the train at all times, since the apparatus is dependent on a constant steam supply. There are two cases where the car might have to stay on a siding: one, at a division point while waiting to be put on a through train, second, at some small siding waiting for a local freight to pick it up. For the first case, steam might be piped to the siding from some near by boiler house or power plant and delivered to the cars in the same manner as Pullman cars are kept warm on sidings and in stations.

For the second case a small ice tank capable of holding about 1 1/2 tons of ice will be placed at the opposite end of the car. This ice will serve as a reserve and will only come into

use when the temperature rises above 32°. As seen from the data taken from freight cars in service, 2 1/2 tons of ice are required for seventy two hours. Therefore this reserve ice will be sufficient to keep the car cold for a period of at least thirty six hours. Based on the proportions used in the car of today this ice tank will occupy about 1 1/2 feet of the loading length of the car. With freight service as efficient as today a car seldom will remain on a siding for more than the thirty six hours and therefore this difficulty will be avoided.

(2) The absorption machine is an entirely closed unit, that is, it requires no operation of valves or levers to keep it running. There are no rubbing parts so that lubrication is not required. In short all it requires is a constant supply of steam and regulation of the expansion valve in order to control the temperature. This last could be accomplished by the use of a thermostat as is done in modern heating plants. The only parts of the apparatus which could get out of order are the pumps for ammonia, brine and cooling water. The small, low pressure, single acting, piston pump is probably one of the simplest machines made and accordingly it has been used in this design. The only overhauling that this pump could possibly require would be lubrication, and an occasional repacking, both of which any mechanic in a division point yard should be able to do. Therefore it is evident that a special attendant for the car would not be required.

(3) Figure I shows a complete arrangement of the car with the proposed system. By comparing this figure with the data given under "Construction of the Modern Refrigerator Car"

it will be seen that the engine room occupies the space of the combined ice tanks. The reserve ice tank of the proposed system occupies space used for freight in the modern car, therefore the proposed plan would cut off a small portion of the loading capacity. But the difference would be very small amounting to not more than 140 cubic feet.

The question of dead weight is one which depends on conditions. When a common refrigerator car is loaded, it requires from 4000 to 11000 pounds of ice to refrigerate it, and it does not appear that the absorption apparatus would be that heavy. When a car is returned empty, the proposed plan would add to the dead weight.

There are then the two cases, in one of which, the loaded car, the absorption machine has the advantage in dead weight, and in the other, the empty car, the present method of icing has the advantage.

(4) As calculated the heat required in the generator is 24,836 B.t.u. per hour. Assuming that the pumps use steam at 50 pounds pressure and that their combined steam consumption is 200 pounds per hour, the heat used is

$$200 \times 1173 = 234,600 \text{ B.t.u. per hour}$$

The total heat taken from the engine per car will then be 259,436 B.t.u. per hour or 4324 B.t.u. per minute. With an average train of 30 cars this would be 129,720 B.t.u. per minute per train.

With an engine capable of delivering 1600 horse-power, the percent of developed power required to run the apparatus would be

$$\frac{129720}{300 \times 1600} = 27 \text{ per cent}$$

From authorities furnished by the Railway Engineering Department any steam used for other than pulling power causes a corresponding per cent decrease in the tractive power of the engine. Hence if we use 27 per cent of the steam for the refrigerating apparatus, the tractive force of the locomotive will be reduced the same amount. The question now arises as to how much this will effect the speed of the train.

Figure II is a curve showing the relation between the tractive force and the speed in miles per hour. Assuming that the train is running at a speed of thirty miles per hour, which seems to be a fair average, let us see what the effect will be on the speed if the refrigerating apparatus is started. At a speed of thirty miles per hour the curve shown above makes an angle of 45° with the axes, hence if the tractive force is reduced 27 per cent the speed will be cut down to

$$(1 - .27) \times 30 = 21.9 \text{ miles per hour.}$$

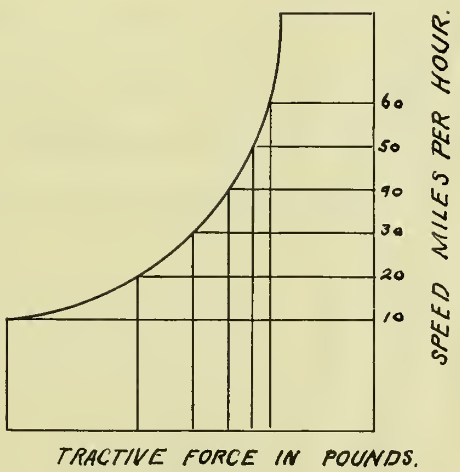


FIGURE II.

In order to keep up the speed so that the train would run on schedule time, the length of the train would have to be reduced, a factor which would greatly increase the cost of operation.

(5) The installation of the absorption system will require no change in the construction of the car now in use, as a glance at the figure will show, for the only necessary change will be the building of an additional insulated wall between the engine and store rooms, and the placing of a small ice tank at the opposite end of the car.

(6) As calculated the total amount of heat required to operate the absorption plant is 259,436 B.t.u. per hour. Steam at 50 pounds pressure contains 1173 B.t.u. per pound, so that the total steam consumption per car will be

$$\frac{259436}{1173} = 221 \text{ pounds per hour.}$$

Assuming that the coal costs $1.50 per ton and that one pound of it will evaporate seven and one half pounds of water, the cost of refrigerating a car from Chicago to New York will be

$$\frac{221}{7.5} \times \frac{1.50}{2000} \times 72 = \$1.60$$

Allowing $4.00 a ton for ice, the cost, under the present system, of refrigerating a car over the same distance is $10.00. This shows that the absorption device can be maintained at very much less expense than the present system.

## XI. Conclusions.

In summing up the foregoing it is seen that of the six points to be considered, the absorption process is lacking in only two, viz: it will cause a reduction in the length of the train and it will take up a little more room than the present icing method. Of the remaining four points, three, the adaptability to present cars, the matter of an attendant and the operation while the car is on a siding, are successfully taken care of in this design; and the fourth, the matter of cost, is a decided advantage in favor of the absorption system.

From the above it appears that this system, considered from a theoretical basis and such practical points as are described, should operate satisfactorily.